MORPHOLOGICAL STUDIES ON THE HEAD AND MOUTH-PARTS OF THE THYSANOPTERA.*

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INTRODUCTION.

The small insects of the order Thysanoptera have four long, narrow, membranous, flat, fringed wings. Only a few veins are present in the wings and when at rest they are laid horizontally along the back. The sucking mouth-parts form a cone at the caudo-ventral margin of the head-capsule. The maxillae, in part, and the left mandible are modified into piercing organs and enclosed within the mouth-cone. The mandibles, clypeus and maxillary sclerites are asymmetrical. The tarsi are two-jointed, bladder-like at the distal end and without claws. The metamorphosis is incomplete.

The order is divided into two suborders, Terebrantia and Tubulifera. The more important distinguishing characters of these are as follows: The female of the Terebrantia has a saw-like ovipositor. This is wanting in the female of the Tubulifera. In the Terebrantia the terminal segment of the abdomen of the female is conical, while that of the male is rounded. In the Tubulifera the distal segment of the abdomen is tubular in both sexes. One or more longitudinal veins

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extend from the proximal to the distal end of the wings in the Terebrantia, while only one, partially developed, median vein occurs in the Tubulifera.

The Terebrantia are divided into two families, Aeolothripidae and Thripidae, while only one family, Phloeothripidae, occurs in the Tubulifera. It is generally stated by investigators in this field that the Terebrantia are the more generalized and of the two families in this suborder the Aeolothripidae are the more primitive. The following brief summary of the evidence as discussed by Uzel in his "Monographie der Ordnung Thysanoptera," page 22, supports the above statement.

The wing characters of the Terebrantia are more generalized than those of the Tubulifera. The wings of the Terebrantia possess one or more complete longitudinal veins and in some cases cross veins, while the Tubulifera have only one partially developed longitudinal vein and no cross veins. Cross veins among the Terebrantia are present only in the family Aeolothripidae. The antennae of most Aeolothripidae are nine-segmented while in all other thrips except the genus Heterothrips there are six to eight segments found. The maxillary palpi of the Aeolothripidae are four-segmented, while those of the Thripidae are usually three-segmented and those of the Phloeothripidae are composed of two long segments. The labial palpi of the Aeolothripidae are always four-segmented while those of other thrips have but two segments. The above data permit the assumption that the Terebrantia are more primitive than the Tubulifera. This assumption is substantiated by the comparative studies of the suborders made in this paper.

The primary purpose of this research is to reach as definite a conclusion as possible in respect to the interpretation of the asymmetrical mouth-parts of the Thysanoptera. The literature of this subject shows a decided diversity of views as to their homology and function. Some investigators consider the mouth-parts as fitted for biting, and others as fitted for sucking. The more recent workers, while agreeing that they are of a sucking type, yet disagree as to the homology of the mouth-parts. Besides the study of the mouth-parts, many interesting head structures have been observed. Of these the pharynx, salivary glands and head-glands are discussed and figured.

In view of the limited nature of the morphological studies of former workers, specimens of as many species of thrips as possible were secured for this work in order that an extensive view of the conditions in the order might be observed. Twelve or more species were used and of these the following nine were identified: (1) Heliothrips femoralis Reuter, (2) Frankliniella tritici Fitch, (3) Thrips physapus Linne, (4) Cephalothrips yuccæ Hinds, (5) Haplothrips verbasci Osborn, (6) Thrips tabaci Lindeman, (7) Chirothrips manicatus Haliday, (8) Anaphothrips striatus Osborn, (9) Limothrips cerealium Haliday.

The first five species in the above list are very abundant in the vicinity of Urbana and as living material was necessary for certain methods of preparation used, the most of my observations were made on these. Fortunately these have proven to be typical and also comparatively easy to dissect and section. Heliothrips femoralis was present thruout the year in its nymphal and adult stages in the city and university greenhouses. Cephalothrips yuccæ was found thruout the year between the closely appressed leaves of the crown of the yucca plant, Yucca filamentosa. Its nymphal stages are abundant from April to December. Only the adult stages of the following were found: Frankliniella tritici occurs in great numbers in the flowers of peonies, roses, composites, etc. Thrips physapus was very abundant in the flowers of dandelions and Haplothrips verbasci can be secured the year around on mullein. Of the above five genera, Heliothrips, Frankliniella and Thrips belong to the suborder Terebrantia while Cephalothrips and Haplothrips belong to the suborder Tubulifera. The nymphs of Heliothrips and Cephalothrips and the adults of all five species mentioned have received similar treatment and observation.

Thruout the following discussions the structures as they exist in the generalized Terebrantia are considered first and the Tubulifera are compared with them. The generic names have been used in the different discussions and on the figures since only a single species of each genus has been considered. The term nymph is used in the following pages to designate the feeding, active, immature stages. In most cases only the older nymphs were used, however, a few observations were made on the early instars, but these did not differ from the

later instars. The term semi-pupa is used in this paper for the semi-quiescent instar just before the adult stage and it is only referred to in the suborder Tubulifera.

METHODS.

For general purposes thrips should be killed in boiling water and preserved in 70 per cent. alcohol. When only the chitinized parts are desired, living or preserved specimens should be boiled for ten or fifteen minutes in a 10 per cent. solution of potassium hydroxide, then reboiled in water to remove the alkali, and finally preserved in 70 per cent. alcohol. Living material treated in the above manner is better than preserved material, for preservation in alcohol tends to make the specimens too brittle for careful dissection.

The use of a Leitz binocular microscope made possible the dissection of the minute mouth-parts. A number of media were tried in which to make dissections; carbol-aniline oil proved to be the best. Its good qualities are that it evaporates slowly and will clear specimens from any grade of alcohol above 50 per cent. If it be desirable to stain with safranin or orange G the stain can be dissolved in 95 per cent. alcohol and will readily mix with the carbol-aniline oil.

The staining of the material for dissection with safranin proved to be very useful in differentiating the almost colorless mouth-parts of some of the species. In using aniline oil in any form one precaution must be observed; as much as possible of the oil should be removed with a blotting paper or a dry rag or by replacing the carbol-aniline oil with carbol-xylene or xylene before mounting in balsam. If the oil be not removed the media in which the parts are immersed will eventually darken.

Material for sections was fixed with hot (80° C.) corrosive sublimate (saturated corrosive sublimate in 35% alcohol plus 2% of glacial acetic acid) for 15 to 30 minutes, which was replaced by 70% alcohol containing a few drops of iodine for 24 or more hours.

Paraffin having a melting point of 52-54 C. gave a sufficiently firm medium in which to cut sections as thin as five microns. Erhlich's and Delafield's haematoxylins were used for staining sections on slides and orange G. or safranin for counter-staining. The best results were obtained by staining punctured specimens in toto for 24 hours in Delafield's haematoxylin or from 3 to 7 days in borax carmine.

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FIXED PARTS OF THE HEAD.

In the order Thysanoptera the gross arrangement of the head and mouth-parts (fig. 1, 2, 5, 8, and 11.) is homologous with the corresponding arrangement of the head and mouth-parts of a generalized homopteron. The cone-like mouth-parts are attached to the caudo-ventral portion of the head-capsule and project caudad between the prothoracic legs, and the antennae are located at the extreme cephalic margin of the head between the compound eyes (fig. 1 and 8).

HEAD-CAPSULE (fig. 1, 2, 5, 7, 8, 9, and 11).—Head structures in thrips differ in many respects from those of a generalized insect. In the head-capsule nearly all of the sclerites are completely united and all traces of sutures have been lost. On account of this union the following areas of the head, front (fr.), vertex (vt.), genae (g.), and occiput (o.), are designated only in a general way on the figures. The labrum and the

asymmetrical clypeus are the mesal pieces on the ventral aspect of the mouth-cone. The compound eyes are located at the latero-cephalic corners of the head-capsule, and the ocelli when present are between the compound eyes on the dorsal aspect of the head.

Heliothrips femoralis (fig. 1, 2, 5, 7, 12, 13, and 19).—A line extending between the vertex and the mouth-cone on the head of a nymph of Heliothrips has a dorso-ventral position, while a similar line on the head of an adult has a cephalo-caudal direction. The position of this line or axis in the nymph suggests a similarity to the position of the head of an orthopteron (Acrididae), while the position of the head of the adult is similar to the position of the head of an homopteron (Cicada).

The head-capsule of the nymph is non-reticulated and slightly chitinized, while that of the adult is highly reticulated and heavily chitinized. The mouth-cone of the nymph occupies more than one-half of the cephalic aspect of the head-capsule and extends ventro-cephalad, while in the adult it is comparatively smaller and projects ventro-caudad.

Two similar caudal projections (c. a.) arise from the ventro-caudal margin of the head-capsule of the nymph and extend for a short distance as narrow pieces between the maxillary sclerites (mx. s.) and the submentum (sm.). In the adult of Heliothrips the caudal projections (c. a.) differ from those of the nymph in that they are decidedly asymmetrical. The left projection is broadly joined to the head-capsule while the broad right projection has a narrow, neck-like attachment. This striking asymmetry is possibly due to the excessive lateral extension of the clypeus toward the right side. The asymmetry of the caudal projections of other adult Terebrantia such as Thrips physapus Linne (fig. 3 and 6) is not as prominent as that found in Heliothrips. The caudal projections articulate along their dorsal sides against certain sclerites of the prothorax.

The asymmetry of the head-capsule of the nymph and adult is very evident in a frontal view (fig. 1 and 13). About half-way between the meson and the left side of the head-capsule on the ventral margin of the front there is a decided recurrent angle which is very distinct in the adult. The thickenings, depressions, and invaginations on the frontal area of the head will be discussed under the internal head-skeleton.

Cephalothrips yuccæ (fig. 8, 9, 11, 17, 18, and 20).—A line extending between the vertex and the mouth-cone on the head of a nymph or adult of Cephalothrips has a cephalo-caudal position and thus in all its stages the position of the head-capsule resembles the position of the head of an homopteron (Cicada.). The nymph of Cephalothrips is very different from the nymph of Heliothrips.

The head-capsule of the nymph and adult is smooth and non-reticulated. The mouth-cone of the nymph occupies about one-half the ventral aspect of the head (fig. 17), while in the adult it is reduced to about one-third the ventral aspect of the head (fig. 8). This reduction is clearly shown in the semi-pupal stage (fig. 20). The dotted line across the head indicates approximately the point of attachment of the mouth-cone as it would be in an active nymph. This line is distinguishable in the early stages of the semi-pupa by a difference in the staining quality of the two areas on the ventral aspect of the head. With the reduction of the mouth-cone of the Tubulifera, striking modifications have resulted in the form of the clypeus, the left maxillary sclerite, and the piercing organs. The modification and the reduction of these parts during metamorphosis are of great value in determining their homology.

Symmetrical, caudal projections (c. a.) are present at the ventro-lateral margins of the head-capsule of the nymph and adult. The caudal projections of the adult are prominent and terminate in distinct acetabula which fit against certain sclerites of the prothorax (p. s.). This arrangement permits of a dorso-ventral movement of the head.

The asymmetry of the caudal margin of the front of the adult is not prominent and in the nymph no asymmetry can be seen. The recurrent angle in the adult is located in a position similar to that in Heliothrips.

An unidentified suture (s.) occurs on the lateral aspect of the head-capsule of the adult dorsad of the caudal projections. There is also an indication of a suture along the dorso-caudal margin of the head. This suture along with the thickenings and invaginations on the frontal and genal areas of the head will be considered later with the discussion of the internal head-skeleton.

Clypeus and Labrum.—The clypeus and labrum are the mesal pieces on the ventral aspect of the mouth-cone.

Heliothrips femoralis (fig. 1 and 13).—The adult and nymph show no marked differences in the form of the clypeus and labrum. The clypeus (cl.) is the large asymmetrical piece, and the convex piece at its distal end is the labrum (lr.). Garman and other workers have considered the area cephalad of the line f as the clypeus and the area ventrad of this line as the labrum. With this interpretation one meets with considerable difficulty in homologizing the parts in the two suborders. If the line f is a suture, it can not be the clypeo-labral suture, but must be the proximal margin of the clypeus. The area between this so-called suture and the front is a broad hyaline membrane (me.). In safranin-stained material, it is slightly colored while in sagittal sections stained in haematoxylin it shows a decided blue tinge. The above interpretation of the line f may be correct, but a better interpretation seems to be that it marks the point where the heavily chitinized, proximal end of the clypeus becomes more or less membranous, and thus permits the dorsal and lateral movements of the mouth-cone. The line f is located in a deep fold from which point the mouth-cone extends in a caudo-ventral direction in the adult and cephalo-ventrad in the nymph. A distinct line or suture (s.) can be seen extending from the recurrent angle on the front to the left lateral end of the line f. This suture is the left lateral margin of the clypeus and shows distinctly in the nymph of Heliothrips (fig. 13) and in the adult of Thrips physapus (fig. 3). This evidence supports the interpretation that the entire area from the front to the small convex labrum is the clypeus. Garman's drawing of Limothrips cerealium shows clearly the above clypeal and labral areas even tho he interprets the parts differently.

The clypeus (cl.) is an asymmetrical triangle with its right latero-cephalic angle decidedly more cephalad than its left latero-cephalic angle. The left margin of the clypeus is a comparatively straight line from the front to the labrum and nearly parallel with the meson, while the right margin in the adult is a curved line and extends at a decided angle to the meson from the labrum to the point of attachment of the right caudal projection with the head-capsule. This unique asymmetry is characteristic of all the Terebrantia examined.

Cephalothrips yuccæ (fig. 8 and 17).—In the nymph of Cephalothrips the clypeus (cl.) is a long, V-shaped, nearly symmetrical piece attached to the caudal margin of the front (fr.). The fronto-clypeal suture between the clypeus and the head-capsule is wanting. The small, distinct, convex piece at the distal end of the clypeus is the labrum (lr.). The clypeus of the semi-pupal stage is smaller than that of the nymph on account of the reduction of the mouth-cone. It is symmetrical and shows a distinct fronto-clypeal suture, but the clypeo-labral suture is not present, however, it is indicated by indentations on the lateral margins of the clypeus near the distal end of the mouth-cone. The ventral margin of the labrum is bilobed indicating its future adult structure. Within the semi-pupal parts the developing adult structures can be seen.

In the adult (fig. 8) the clypeus and labrum have been modified thru the reduction of the mouth-cone, but they are distinctly differentiated by sutures and color differences. The above interpretation of the clypeus and labrum, which is the one given by Muir and Kershaw, agrees with the nymph and adult condition found in all Tubulifera observed and it also explains the condition found in the Terebrantia. Garman's interpretation of the clypeus and labrum in the Terebrantia presents difficulties when an attempt is made to apply it to the conditions found in the Tubulifera.

Compound Eyes.—The compound eyes of Heliothrips (fig. 12, 13 and 19) are present in the nymph as small, oval areas on the lateral aspects of the head-capsule in the dorso-caudal region. There are five, round, indistinct bodies in each elevated area. In the nymph of Cephalothrips (fig. 17 and 18) two similar, elevated, small, oval areas are present on the cephalo-lateral aspects of the head, but these possess no facets or round bodies. In the adult stage of both species (fig. 1, 2, 5, 7, 8, 9, and 11) there is a large, reniform area filled with facets, covering the latero-cephalic areas of the head. In the adult of Heliothrips the eyes protrude beyond the general curvature of the head, the facets are scattered, few in number and variable in size. From a ventral view six large, opaque facets can be seen. These larger facets retain their muddy brown color, and do not become clear and transparent as do the remainder

of the facets when they have been treated with potassium hydroxide. In the adult of Cephalothrips the eyes do not protrude from the head-capsule, the facets are numerous, clear, and all approximately of the same size.

Ocelli.—The ocelli as far as observed are three in number. They are situated on the dorsal aspect of the head between the compound eyes in the form of a triangle with the median ocellus on the cephalic side. In the two species figured the ocelli of Heliothrips (fig. 7) are clear oval bodies located on a small, elevated, triangular area, while the ocelli of Cephalothrips (fig. 9) are clear, circular bodies, larger than the facets of the compound eyes, more distant from each other than those of Heliothrips and not elevated above the general plane of the head-capsule. No traces of ocelli were found in the nymphs.

Tentorium or Internal Head-skeleton.—Under this heading only those internal structures found in the head that pertain to the tentorium will be considered. For other internal parts the discussions on the maxillae, pharynx and salivary glands should be consulted.

One finds within the head of a generalized insect a definite arrangement of rod- and plate-like structures which go to support the internal organs and furnish points of attachment for muscles. These rods or plates extend from three pairs of openings on the head-capsule. These openings are known as the invaginations of the anterior arms, dorsal arms and posterior arms of the tentorium. The invaginations of the anterior arms are usually associated with the lateral margins of the clypeus and with one of the points of articulation of the mandibles. The invaginations of the dorsal arms are associated with the points of attachment of the antennae. The invaginations of the posterior arms are associated with the occipital foramen, and the point of attachment of the maxillae. These generalized relations become modified in the various orders and families of insects. The invaginations may disappear and the rods and plates undergo striking changes or become atrophied. The important point, however, is that in all orders of insects, so far as observed, the invaginations and the arms of the tentorium are always associated with the appendages named. These associations exist in thrips and an attempt will be made to show that they have an important bearing on the homology of their mouth-parts.

On account of the close relation existing between the Homoptera and the Thysanoptera, a comparison will be made between the internal head-structures of Cicada and those of thrips. Figure 29 is a lateral view of the entire tentorium of Cicada showing the invaginations and the arms. The invaginations of the anterior arms of the tentorium (i. a.) occur at the ventro-lateral ends of the clypeus while the dorsal arms are invaginated (i. d.) just ventrad of the antennae. Between these two pairs of invaginations distinct, thin, broad, chitinized plates extend which are the anterior arms of the tentorium (a. a.). The invaginations of the posterior arms (i. p.) are found on the lateral margins of the occipital foramen adjacent to the maxillary plates described by Muir and Kershaw. These invaginations give rise to the broad, plate-like posterior arms (p. a.) which nearly surround the occipital foramen. A small chitinized rod extends across the occipital foramen between the dorsal ends of the posterior arms. This rod is the body of the tentorium (b. t.) and from its mesal portion two long, slender rods arise which extend cephalad (d. a.) and unite with the invaginations of the dorsal arms (i. d.). These two rods are the dorsal arms of the tentorium. In Cicada the ventral ends of the posterior and anterior arms unite on each side (xc.) and between these united arms there extends across the meson a distinct plate or bridge (zc.). The usual association between the appendages of the head and the tentorium among insects may be found in Cicada; that is, the invaginations of the posterior arms (i. p.) are near the point of attachment of the maxillary, piercing organs with the head-capsule; the mandibles are associated with the anterior arms but on account of their great length and the excessive development of the clypeus, they are not connected near the invaginations of the anterior arms (i. e.) but connect with the head-capsule slightly laterad of the anterior arms near the invaginations of the dorsal arms; and the invaginations of the dorsal arms (i. d.) are adjacent to the antennae.

As mentioned before, the internal head-skeleton of thrips undergoes considerable modification and this is well illustrated in the various heads figured. In the nymph of Heliothrips (fig 12, 13, 19 and 28) the tentorial structures are nearly all present, while in the adult of Cephalothrips (fig. 8 and 33)

extensive atrophy has taken place and those tentorial parts which still remain can only be interpreted by comparison with the more generalized conditions in the nymphs.

On the cephalic aspect of the head of a nymph of Heliothrips (fig. 13) two sets of invaginations can be seen. One pair exists on the ventral margin of the front (i. a.) and the second pair (i. d.) a short distance dorsad of these. Since the invaginations on the ventral margin of the front are close to the lateral edges of the wide clypeus, they actually occur on the lateral aspects of the head-capsule. This is especially true of the invaginations on the right side. Distinct chitinous arms extend between the invaginations on each side (a. a.). The invaginations, as described, are homologous with the two pairs of invaginations on the cephalic aspect of the head of Cicada. The two invaginations on the ventral margin of the front are believed to be the invaginations of the anterior arms of the tentorium (i. a.) while the invaginations dorsad of these are the invaginations of the dorsal arms of the tentorium (i. d.). The rods between the invaginations on each side are the anterior arms (a. a.). Chitinized thickenings (d. a.) extend dorso-caudad from each of the invaginations of the dorsal arms (i. d.) and these thickenings on reaching the caudal margin of the head-capsule turn caudad and run parallel with the caudal margin of the head (p. a.) to the distal ends of the caudal projections (c. a.). On comparison with Cicada the dorso-caudal extensions that project from the invaginations of the dorsal arms to the caudal margin of the head are homologous with the dorsal arms of the tentorium (d. a.) while the chitinized thickenings along the lateral margins of the occipital forearm (p. a.) are considered as homologous with the posterior arms of the tentorium. In thrips the body of the tentorium is wanting, consequently the dorsal arms (d. a.) connect directly with the posterior arms (p. a.). The invaginations for the posterior arms (i. p.) were not identified in any of the thrips examined. In a few cases it seemed as though the invaginations were present near the ventral end of the posterior arms (p. a.) where the thickenings (x.) on the ventral margin of the head-capsule came in contact with the posterior arms. Thus far the tentorium of a nymph of the Terebrantia can be homologized with the tentorium of Cicada.

The differences which occur between the tentorium of a Cicada and a thrips can be largely accounted for in the differences between the head-structures. The head-capsule of a thrips is elongated cephalo-caudad while this extension of the head-capsule of a Cicada is short. Furthermore in a Cicada the clypeus is large and occupies the greater part of the cephalic aspect of the head but this is not so in thrips. The invaginations of the dorsal arms (i. d.) in thrips are apparently not associated with the antennae. This seemingly lost association is undoubtedly due to the excessive cephalic or dorsal growth of the head-capsule. The location of the invaginations of the anterior arms of the tentorium (i. a.) in thrips resembles the location in a generalized insect since they are near the cephalo-lateral corners of the clypeus and not near the distal ends of the clypeus as in Cicada.

The following tentorial structures are present in thrips which are difficult to account for on the basis of the homology with the structures in Cicada. A distinct thickening extends along the caudal or ventral margin of the head-capsule between the caudal projections (x. and z.). This thickening is present in all thrips. In the nymph of Heliothrips the portion of the thickening (x.) between the ventral end of the right anterior arm (a. a.) and the right posterior arm (p. a.) is wanting. The above thickening may be secondary or possibly may be homologized with the union of the ventral ends of the anterior and posterior arms of Cicada (xc. and zc.). In all the thrips examined, distinct, chitinous, ental projections arise from the invaginations of the dorsal arms. These projections are not present in Cicada.

In considering the tentorium of thrips figured in this paper, a distinct atrophy of certain portions and parts can be seen. In the adult of Heliothrips (fig. 1 and 27) a thickening occurs (x. and z.) along the caudo-ventral margin of the head-capsule and from this thickening other thickenings (p. a.) arise which extend to the caudal projections (c. a.) of the head-capsule. Of the anterior arms (a. a.) only the left one is present. The left anterior arm is located in a depressed line extending between the invagination of the left dorsal arm and the recurrent angle on the caudal margin of the front. The dorsal arms (d. a.) are wanting and also the posterior arms (p. a.) except for a small portion on the caudal projections (c. a.) of the

head-capsule. The invaginations of the anterior arms are very indistinct in this species due to the thick, highly chitinized and reticulated nature of the head-capsule. This characteristic also makes it difficult to differentiate the tentorial thickenings. However in Thrips physapus (fig. 3 and 6) the invaginations of the anterior (i. a.) as well as the tentorial thickenings are readily made out in dissected heads that have been stained. The invaginations of the dorsal arms (i. d.) with their ental projections show very clearly in the adult of Heliothrips and likewise in all thrips.

In the nymph of Cephalothrips (fig. 22) a still greater reduction of the tentorium apparently exists. This apparent loss, however, may be due to the fact that it is impossible to distinguish all the parts on account of the extremely thin and membranous nature of the head-capsule. Only the invaginations of the dorsal arms (i. d.) with their ental projections show very clearly. By careful staining one can distinguish a thickening (a. a.) occupying the position of the left anterior arm of the tentorium. This thickening extends from the invagination of the left dorsal arm (i. d.) to the point where the asymmetrical piercing organ (l. md.) unites with the head-capsule. In this feature there is a remarkable similarity between the nymphal head of the Tubulifera and the adult head of the generalized Terebrantia.

The tentorium of the adult of Cephalothrips resembles somewhat that of Heliothrips. In Cephalothrips the anterior arms of the tentorium are atrophied but the invaginations of the dorsal arms with their projections are very distinct and the invaginations of the anterior arms can be identified in dissected material that has been stained, if a careful examination is made of the caudal boundary of the head-capsule (z.) at the point where the lateral margins of the clypeus are in contact with the front. Besides the thickenings that are similar to those of Heliothrips two thickenings extend cephalad (mx. p.) on the lateral areas of the head-capsule. These cephalic-extending thickenings clearly arise from the thickenings (z.) about the caudo-ventral margin of the head-capsule and terminate in enlarged, elevated ends which possess acetabula in which the proximal pieces of the paired, piercing organs (mx.) articulate. One can readily see that these mandibular pillars, as Muir and Kershaw call them, are of a tentorial origin.

A distinct strip (st.) is present on the caudal margin of the head-capsule of Cephalothrips and extends between the short sutures (s.) which arise from the latero-caudal margin. Stained material shows clearly that this area (st.) is structurally different from the head-capsule cephalad of it. On the ends of this area (st.) two depressions are present which are similar in many respects to the invaginations of the tentorium. If these are invaginations of the posterior arms then this is a thickening composed of the union of the posterior arms about the dorsal margin of the occipital foramen. This interpretation is rather questionable since no invaginations of the posterior arms have been seen in the more generalized thrips.

As a conclusion to the above discussion on the internal head-skeleton, the following statements are of importance. The tentorium and the associated mouth-parts of an homopteron such as Cicada can be interpreted on comparison with the same parts in a generalized insect. The arms of the tentorium and their respective invaginations in the nymph of one of the Terebrantia can be homologized with the tentorial parts of a Cicada. On the basis of this homology the specialized and atrophied conditions existing in the adults of the Terebrantia and in the nymphs and adults of the Tubulifera can be interpreted.

Furthermore, on the basis of this homology between the tentorium of thrips and other insects an attempt will be made to demonstrate the association of the mandibles and the maxillae with their respective tentorial parts. This should give conclusive evidence as to the correct interpretation of the two sets of piercing organs. See discussion on mandibles and maxillae for this demonstration.

MOVABLE PARTS OF THE HEAD.

The movable parts of the head will be considered in the following order: antennae, labium, maxillae and mandibles. In the discussion of the movable appendages those of the generalized Terebrantia will be considered first and then the homologous structures of the Tubulifera will be compared with them.

Antennae (fig. 4).—The antennae of the adult of Heliothrips are about twice the length of the head-capsule, eight-segmented and reticulated with chitinous elevations corresponding to the reticulations (rt.) on the head-capsule. The shape, size, reticulated character and the setal arrangement are shown in the figure. Segments one, two, six, seven and eight are of a brownish color similar to the head-capsule while the remaining segments are but slightly pigmented. The distal end of segment four gives rise to a thin, hyaline, two-branched sense cone (s. c.). The sense cones are not present in the antennae of the nymph. Except for this the antennae of the nymph are structurally similar to those of the adult.

The antennae of the nymph and adult of Cephalothrips resemble each other and are of the same number of segments, eight, providing the very small pieces at the distal ends of the nymphal antennae are considered as segments. In the first stages of the semi-pupa (fig. 20) the antennae appear as mere buds at the cephalic margin of the head-capsule. As the insect becomes older, the antennal cases increase in size and length until they extend around the lateral margins of the head-capsule. A late stage of the semi-pupal instar shows segmentation on the distal portions of the antennal cases. The eight-segmented antennae of the adult are about one and one-third times longer than the dorsal aspect of the head-capsule and have a yellow color thruout, except the two basal segments, which are of a brown tinge. The general shape, size and setal arrangement of the segments is shown in figure 10. Segments three, four, five and six each possess at their distal end a pair of simple, hyaline, spine-like sense cones (s. c.). The sense cones are wanting in the nymph.

Labium.—The mouth-parts of Hemiptera are fitted for sucking. In this adaptation the labium is modified into a long, trough-like beak, enclosing the bristle-like mandibles and maxillae. The mouth-parts of Thysanoptera are also fitted for sucking. The adaptation in thrips, however, is not confined to the specialization of one part of the mouth, but the clypeus, labrum, maxillary sclerites and labium together form a broad and blunt mouth-cone, enclosing the needle-like mandibles and maxillae. Of these two types of sucking mouth-parts, those of the Thysanoptera more closely resemble a generalized

biting type of mouth. The arrangement of the parts of the mouth-cone, the presence of maxillary and labial palpi and other characteristics in Thysanoptera show this close similarity.

The labium of the nymph and adult of thrips is similar (fig. 60 and 61). The entire convex, caudal area of the mouth-cone is the labium. From a caudal view it is distinctly triangular in outline, with the apex at its distal end and from a ventral or lateral view it is convex. The labium is attached along its lateral margins to the triangular, palpus-bearing sclerites (mx. s.) while its dorsal margin is united with the ventral membranous portion of the prothorax. It is composed of two distinct sclerites separated by a transverse suture (s.). The proximal piece is the submentum (sm.) and the distal piece is the mentum (m.). The mentum has at its distal end a membranous area which gives rise to a pair of small, two-segmented palpi (lb. pl.). The distal margin of the mentum possesses two small, chitinous projections considered by Hinds as paraglossae (pr.).

Heliothrips femoralis.—The labium of Heliothrips (fig. 60) corresponds to the general description. The dorso-ventral length of the labium is about the width of the submentum. The ectal surface of the labium is slightly reticulated.

Cephalothrips yuccæ.—The labium of Cephalothrips (fig. 61) corresponds to the general description. The mouth-cone of Cephalothrips is short, consequently the dorso-ventral length of the labium is less than one-half the width of its submentum (s. m.). The submentum is heavily chitinized along its proximal margin as indicated in the figure. The mesal portion of the suture (s.) between the submentum and the mentum is obsolete, but its lateral ends show distinctly. The two projections or paraglossae at the distal end of the labium are united and form a lip-like structure over which the movable, paired, piercing organs pass. This lip is indicated by shading in figure 8.

Maxillae.—A pair of asymmetrical, triangular, palpus-bearing sclerites (mx. s.) are situated on the lateral sides of the clypeus and labrum in the mouth-cone of the Thysanoptera (fig. 1 and 8). The palpi (mx. pl.) of these pieces are usually two- or three-segmented. A comparison of these palpus-bearing sclerites with similar sclerites in Cicada shows that

they are homologous with the so-called maxillary plates described by Muir and Kershaw. The segmented palpi however are wanting on the maxillary plates of the Hemiptera. Their presence in Thysanoptera indicates a more primitive condition and also is conclusive evidence that these sclerites are maxillary in origin.

The lateral margins of the maxillary sclerites (mx. s.) are turned into the mouth-cone, thus giving rise to ento-mesal extensions (et.) or plates. These extensions, toward the distal end of the mouth-cone, unite with the lateral edges of the pharynx and form sheaths or troughs over which the needle-like portions of the paired piercing organs (mx.) pass. This is clearly shown in cross-sections of the pharynx (fig. 38-44 and 51-57).

Two sets of piercing organs are found in the mouth-cone of all Thysanoptera (fig. 22, 27, 28 and 33). The paired, symmetrical set will be considered first because of their relation to the maxillary sclerites. Each one of the paired piercing organs is composed of three parts (mx.). Its distal portion is long, grooved, needle-like, and swollen at the proximal end. The middle portion is short and thick and separated from the distal portion by a distinct suture while its proximal end is connected to the proximal portion by a movable joint. The proximal portion is a heavy piece and in some cases three or four times as long as the middle portion. Also its proximal end articulates against the cephalic edge of the maxillary sclerite (mx. s.) or in an acetabulum on an elevated pillar (mx. p.) arising from the head-capsule. This articulation in all cases is either directly or indirectly associated with the maxillary sclerite. The presence of two movable joints in this piercing organ makes its extension into a straight line possible. This extension occurs when the organ functions. When the paired piercing organs are extended beyond the mouth-cone the grooved, needle-like piercing portions interlock and such a union naturally makes an effective tool. This interlocking is readily seen in sectioned material (fig. 25).

The muscles which bring about the extension of the paired piercing organs (mx.) are attached to the proximal pieces. Each extensor muscle is connected with the ental surface of the maxillary sclerite and the mesal edge of the proximal piece when the piercing organs (mx.) are within the head-capsule.

The above characteristics concerning the maxillary sclerites (mx. s.) and the paired piercing organs (mx.) may be found in all thrips as far as observed and one can safely infer that the similar parts in all thrips are homologous and should have the same interpretation thruout the order. In a like manner it will be found that a similar homology exists between the asymmetrical piercing organs of all thrips. This homology eliminates the suggestion offered by Muir and Kershaw that in the two suborders of the Thysanoptera a distinct difference of interpretation of the piercing organs might be possible.

Heliothrips femoralis (fig. 1, 2, 5, 12, 13, 19, 27, and 28).— The maxillae of Heliothrips are in general typical of the suborder Terebrantia and accord with the general description of the maxillae just given. The maxillary sclerites (mx. s.) of the nymph and adult resemble each other except that the palpi of the nymph are four-segmented while those of the adult consist of only two long segments. The palpi of some of the more generalized adult Aeolothripidae are four-segmented and thus the four-segmented palpi of the nymph indicate a generalized condition. The maxillary sclerites (mx. s.) are decidedly asymmetrical. This asymmetry is more pronounced in the adult (fig. 1). The proximal ends of the maxillary sclerites of the adult are not in direct contact with the head-capsule. There are distinct membranous areas (me.) between them. In this particular species the membranous areas (me.) continue from the cephalic margin of the maxillary sclerites to the bases of the palpi where the membranes broaden and surround the proximal segments. The membranous strip on the left maxillary sclerite is more extensive than the one on the right. The ento-mesal extensions (et.) arising from the lateral margins of the maxillary sclerites resemble closely the general description of these parts and they can be readily made out in figures 28 and 39 to 44.

The paired piercing organs of Heliothrips (fig. 27 and 28, mx.) are but slightly longer than the maxillary sclerites and this is true of the Terebrantia in general. The structure of their paired piercing organs resembles the general description of these parts. The proximal piece in the nymph is L-shaped and the base of the L articulates along the dorsal margin of the maxillary sclerite (mx. s.). The proximal piece in the adult,

likewise articulates against the cephalic margin of the maxillary sclerite and has an L-shape, but the base of the L is greatly reduced and the erect portion is longer, heavier and of the same thickness thruout. The above relation between the paired piercing organs and the maxillary sclerites is true of all Terebrantia as far as observed (fig. 14, 21 and 32). Since the paired piercing organs in the Terebrantia are directly connected with the cephalic margin or the latero-cephalic corners of the maxillary sclerite, one may conclude, as Garman has already done in his work on Limothrips cerealium, that these piercing organs are parts of the maxillae. If such is the case the paired piercing organs may be modified lacinia as Garman has suggested. According to Garman and other workers these organs consist of only two pieces, but in all species observed three distinct pieces can be found. The suture between the needle-like distal portion and the middle piece is wanting in the figures of other workers.

Karl Jordan and other workers have interpreted the paired piercing organs (mx.) as mandibles. Jordan worked with Heliothrips haemorrhoidalis, a form closely related to Heliothrips femoralis. His proof is largely founded on the statement that the embryonic development shows that these pieces are mandibles. The evidence in support of this statement is wanting in both figures and discussion. He has but one figure of the embryonic condition and in this the relation of the so-called mandibles to the head-capsule and other parts is not clear. The real difficulty with Jordan's interpretation rests in the fact that he has wrongly identified the asymmetrical piercing organ (l. md.) and consequently in his search for mandibles he has from necessity tried to show that the paired piercing organs are mandibles.

The conclusion in regard to the paired piercing organs of the Terebrantia is that they are portions of the maxillae, and the following additional evidence will be presented to substantiate the same.

In the first place, if these paired piercing organs are mandibles, how can one explain their three piece structure? Mandibles usually have only one solid piece, but maxillae on the other hand are composed of several sclerites and upon modification they might assume the conditions found in thrips. As to the exact

homology of these pieces it is difficult to determine. However, on the basis of the maxillae of other insects, one finds that the galea is usually segmented while the lacinia is not. In most sucking insects the galea is present and the lacinia may be wanting. It would seem that the paired piercing organs were galea rather than lacinia as Garman has suggested. For convenience of description the paired piercing organs will be designated as the maxillary setæ (mx.).

Strong evidence is likewise found in the relation existing between the paired piercing organs and the tentorium of the head. The maxillae in generalized insects are associated with the invaginations of the posterior arms of the tentorium and this relation was shown to be true with Cicada. On the basis of the homology between the tentorium of Cicada and thrips it was shown that the thickening about the occipital foramen in the nymph of Heliothrips (p. a.) are homologous with the posterior arms of Cicada. In the nymph and adult of Heliothrips the paired piercing organs are closely associated with the ventral or caudal ends of these thickenings or so-called posterior arms. As mentioned before, no invagination of the posterior arms of the tentorium could be found in this genus of thrips; however, from the close association of the paired piercing organs with the posterior arms of the tentorium we may conclude that the generalized relation between the posterior arms of the tentorium and the maxillae holds for thrips as well as for more primitive insects.

Further evidence is found in the fact that in generalized insects the maxillae are always attached to the head-capsule caudad of the mandibles. As was pointed out in the discussion of the head-capsule of thrips, the mouth-cone has been carried around the head until it is now found at the caudo-ventral portion of the head. As a result the mouth-parts have a cephalo-caudal extension rather than the generalized dorso-ventral direction. This rotation of the mouth-parts means that the maxillae should connect with the head-capsule dorsad of the mandibles. The paired piercing organs of the Terebrantia (mx.) are decidedly dorsad to the asymmetrical piercing organ (l. md.), and it will be shown later that the asymmetrical piercing organ is a mandible.

Cephalothrips yuccæ.—The maxillae of Cephalothrips (fig. 8, 11, 17, 18, 20, 22, and 33) are typical of the suborder Tubulifera. The maxillary sclerites (mx. s.) of the nymph (fig. 17) and the adult (fig. 8) are dissimilar in comparative size and symmetry, but both possess a two-segmented palpus (mx. pl.). The long maxillary sclerites of the nymph are nearly symmetrical while those in the reduced mouth-cone of the adult are asymmetrical. This asymmetry in the adult is characterized by a distinct knob (n.) at the cephalic end of the mesal margin of the maxillary sclerite. This knob fits into a notch on the left margin of the clypeus and appears to be a portion of the maxillary sclerite, but a close examination shows that it is only connected with the maxillary sclerite by a narrow strip at its latero-cephalic corner; and a distinct fissure, which extends cephalad and laterad from the point where the clypeo-maxillary suture turns mesad, separates it from the maxillary sclerite. The asymmetrical piercing organ of the adult is associated with the above asymmetry. On comparison with the asymmetry found in the Terebrantia the asymmetry of the Tubulifera is of a decidedly different nature.

The mesal extensions (et.) of the lateral edges of the maxillary sclerites resemble the general description of these parts (fig. 22, 33 and 35). However, a unique modification of these extensions is found in the development of two long, trough-like, cephalic extending arms (mx. g.). These parts serve to guide the long maxillary setæ and have been designated as the maxillary guides. These guides are only present in the Tubulifera, and undoubtedly they have been developed in this suborder on account of the necessity of some kind of a guiding structure for the exceedingly long maxillary setæ. The maxillary guides arise from the mesal part of the sheath (et.) that extends between the lateral edges of the maxillary sclerites at the distal end of the mouth-cone, and project forward into the dorsal portion of the head-cavity to the region of the compound eyes. Cross-sections of the pharynx (fig. 53 and 54) show that in this forward projection they unite with the pharynx. In the nymph they are narrow at their proximal ends but broadly rounded and separate at their distal ends, while in the adult they are trough-like and their distal ends are united in a transverse plate. The long maxillary setæ pass around the

cephalic ends of the maxillary guides and at first are dorsad of the guides. In their caudo-ventral extension they pass along the lateral sides of the trough-like guides and laterad of the pharynx toward the tip of the mouth-cone beyond which the two distal, grooved, needle-like portions interlock and project as a single piercing organ (fig. 25). The maxillary guides show no relation to the tentorial structures of the head.

The paired piercing organs (mx.) of Cephalothrips, except for size, and point of attachment in the adult, resemble the maxillary setæ of Heliothrips. The linear extension of the maxillary setæ in Cephalothrips is due largely to the increased length of the distal and proximal pieces. The large proximal piece in the adult possesses a distinct knob on its mesal margin which serves as a point of attachment for muscles. The resemblance between the maxillary setæ in the nymph or adult of Heliothrips (fig. 27 or 28) and the paired piercing organs in the nymph of Cephalothrips is very striking and important. The feature of significance in the nymph of Cephalothrips is the point of attachment of the paired piercing organs with the cephalic margin of the maxillary sclerites. This shows clearly that the paired piercing organs of Cephalothrips are not only homologous in structure but in point of articulation with the maxillary setæ of the Terebrantia. The paired piercing organs of the Tubulifera are therefore maxillary setæ. The evidence used to prove that the paired piercing organs of the Terebrantia are maxillary in origin will likewise hold for the Tubulifera with the exception of the evidence based on the tentorium, since some of the tentorial structures are wanting in the nymph of Cephalothrips.

The relation of the maxillary setæ to the mouth-parts in the adults of the Tubulifera (fig. 33) is apparently very different from the conditions found in the Terebrantia. The reduction of the mouth-cone explains to a large extent the characteristic modifications of this suborder. In the reduction of the mouth-cone the proximal pieces of the long maxillary setæ (mx.) do not retain their point of articulation with the maxillary sclerites but articulate in acetabula located in special elevated maxillary pillars (mx. p.) on the ental surface of the head-capsule cephalad of the maxillary sclerites. This modification is a result of a mechanical necessity. It would be impossible

for the long maxillary setæ to function if they retained their connection with the reduced maxillary sclerites. However, their connection with the maxillary sclerites is not entirely lost since the thickenings from which the maxillary pillars (mx. p.) arise, extend to the tentorium (x. and z.), which is adjacent to the maxillary sclerites. These thickenings are undoubtedly derived from the tentorium, and since the maxillæ are associated with them they are possibly modifications of the posterior arms (p. a.).

Muir and Kershaw in their work on a species of Tubulifera interpret the paired, piercing organs as mandibles. They give two lines of evidence. In the first place, they show that the asymmetrical piercing organ (1. md.) is a part of the maxillæ, consequently the paired piercing organs must be mandibles. Also they have proved to their own satisfaction by comparison with Rhynchota that the paired piercing organs are mandibles. "The paired setæ we consider as mandibles, homologous to those of Rhynchota." The first part of their evidence will be considered later. In regard to their own statement here quoted there is considerable doubt. They present no satisfactory evidence on this point, and as far as observed, the relations existing in Cicada permit of no such interpretation, as has already been shown. Jordan also studied individuals of the Tubulifera and came to the same conclusions as in his studies on the Terebrantia. The different interpretations of the paired piercing organs in the Thysanoptera of the authors mentioned above has been largely due to an incomplete comparative study of the nymphal and adult stages of both the suborders.

Mandibles.—A large, heavy, unpaired piercing organ (1. md.) is present on the left side of the mouth-cone of all thrips (fig. 2, 3, 11, 12, 18, 22, 27, 28, and 33) while on the right side no such organ is found. Berlese figures the asymmetrical piercing organ as occurring on the right side. Undoubtedly this is a mistake for in no case has such an occurrence been recorded by other workers. This asymmetry of mouth-parts is unique among insects. The asymmetrical, piercing organ connects with the head-capsule at the point where the left margin of the clypeus or the right margin of the maxillary sclerite comes in contact with the front. It is composed of

two parts, which are of about the same length. The distal half is a long, heavily chitinized, hollow spine, while the proximal half is broader, hollow and not as heavily chitinized. Cross and longitudinal sections show a distinct lumen extending thruout its length (fig. 26). At the very tip of the spine it is impossible however to be sure that an opening is present. If such an opening is present then it may serve as an exit for the secretions from the glandular tissue within the basal half of the piercing organ. If the lumen is not a duct for the secretions but a blind tube, then one can explain its presence on the basis that it is the place formerly occupied by the hypodermal cells which formed the cuticle of the spine.

Cross-sections of the pharynx show how the asymetrical piercing organ passes along the cephalic side of a left lateral extension of the pharynx (fig. 40 and 41). This left lateral extension is cephalad of the paired extensions over which the maxillary setæ pass, and only occurs on the left side. In the Tubulifera the left maxillary guide helps to form this extension (fig. 53).

There are large muscles attached to the proximal end of the asymmetrical piercing organ. These muscles connect with the dorsal aspect of the head-capsule and on contraction pull the asymmetrical piercing organ (l. md.) into the mouth-cone. The majority of the specimens examined showed the piercing organ protruding from the concave side of the labrum (lr.). Apparently this is its normal position and it is evidently used in making the first puncture thru the outer cells of the plant tissue. After this puncture is made it is probably withdrawn into the mouth-cone, and the long maxillary setæ are then used to puncture the inner and deeper cell-layers. The withdrawal of the asymmetrical piercing organ from the tip of the mouth-cone also permits the plant juices to pass into the pharynx.

On the right side of the mouth-cone a piece (r. md.) is found which is homologous in position to that of the left, asymmetrical piercing organ (fig. 27). In all cases this piece arises adjacent to the front, between the clypeus and the right maxillary sclerite, and extends to the right cephalo-lateral margin of the pharynx and unites with the same (fig. 40). This union is indicated by a distinct suture in cross-sections of the pharynx.

The invaginations of the anterior arms of the tentorium (i. a.) in thrips are always located on the caudal margin of the front and adjacent to the asymmetrical piercing organ and the above-described piece. This evidence undoubtedly shows that this rudimentary piece on the right side is homologous with the asymmetrical piercing organ on the left.

Heliothrips femoralis (fig. 2, 5, 12, 19, 27 and 28.).—The left asymmetrical piercing organ and its right homologous rudiment are typical of the suborder Terebrantia and correspond to the general description given above. These parts in the nymph and adult closely resemble each other. In the nymph (fig. 28) the left, piercing organ is smaller, straighter, and its two halves less differentiated than in the adult (fig. 27). The basal half of the left, piercing organ is connected with the front by a narrow, chitinized neck. This connection is readily seen in frontal sections of the adult and nymph.

The right, rudimentary piece in the nymph and adult extends as a distinct piece between the right cephalo-lateral margin of the pharynx and the front. This piece is homologous with the asymmetrical piercing organ (1. md.) and resembles somewhat its basal half. The distinguishing differences in these two are their size and the union of the right piece with the pharynx. Jordan represents a prominent projection on the right margin of the pharynx of Heliothrips hæmorrhoidalis. This probably represents the asymmetrical piece above described. Garman found in his work on Limothrips a small, right, asymmetrical structure which he considered to be a rudimentary piece homologous with the left, piercing organ. These two pieces Garman designated as mandibles. This interpretation agrees with my own observations. Garman's own words are, "The organ has every appearance of being a mandible. Its form and its relation to the other mouth-parts and to the epicranium all indicate this. Nothing corresponding to this conspicuous organ is apparent on the right side of the head unless a very small, chitinous structure under the edge of the clypeus is a rudiment of the organ for this side." Garman records the structure of the left mandible as consisting of one solid piece. The writer however, considers the left mandible as composed of two parts. At least in all thrips examined a distinct constriction occurs between the distal spine and the large proximal portion, and to all appearances a

suture is located here. Without any question the mandible is hollow, as heretofore explained. The following evidence goes to show that the asymmetrical piercing organs of the Terebrantia are mandibular in origin.

In the first place, as Garman has already mentioned, the structure, position, and point of connection of the asymmetrical piercing organ with the head-capsule are strong mandibular characteristics. It has already been pointed out that the invaginations for the tentorial arms on the front of thrips are homologous with the invaginations of the tentorial arms on the cephalic aspect of the head of Cicada. The invaginations of the anterior arms of the tentorium on the caudal margin of the front (i. a.) are adjacent to the point of connection of the left and right asymmetrical organs (l. md. and r. md.). This relation shows that the asymmetrical piercing organs of the Terebrantia are undoubtedly mandibles since in generalized insects mandibles are usually associated with the invaginations of the anterior arms of the tentorium.

Furthermore, mandibles in generalized insects are always connected with the head-capsule cephalad of the maxillæ. In the nymph of Heliothrips the asymmetrical piercing organs are connected cephalad of the maxillary setæ but in the adult on account of the change of position of the mouth-cone these connections are ventrad of the maxillary setæ. This relation in the Terebrantia shows clearly that the asymmetrical piercing organs are mandibular in origin.

Karl Jordan interprets the left, asymmetrical piercing organ (l. md.) as a modified epipharynx. He bases his conclusion upon embryological studies. The one embryo figured shows the asymmetrical organ as the upper portion of the anterior end of the alimentary canal. The base of the so-called epipharynx is also connected with the head-capsule. He concludes from this figure that when the adult stage is reached the epipharynx loses all connection with the alimentary canal and becomes more firmly attached to the head-capsule. The above hypothesis in regard to the behavior of the epipharynx is contrary to the relations of these parts in other insects. Jordan likewise failed to account for the right, rudimentary piece (r. md.). On the whole Jordan's interpretation is very unsatisfactory, for it does not explain numerous relations here pointed out.

Cephalothrips yuccæ (fig. 11, 18, 22, 26, 33, 34, 35 and 36).—A striking similarity exists between the ental view of the mouth-parts of a nymph of Cephalothrips (fig. 22) and the adult stage of Heliothrips (fig. 27). This similarity is particularly noticeable in respect to the structure and position of the asymmetrical piercing parts. On the basis of this similarity it is possible to derive the correct interpretation of the asymmetrical, piercing organs. The left mandible (1. md.) in the nymph is a long, nearly straight, stout, two-segmented structure and connects with the caudal margin of the front (f.) at the point where the maxillary sclerite and clypeus unite with the head-capsule. Between this point of connection and the invagination of the left dorsal arm of the tentorium a thickening occurs (a. a.). This thickening is the anterior arm of the tentorium and can be seen in carefully stained and dissected material.

The right, rudimentary mandible in the nymph of Cephalothrips is represented by a distinct chitinized thickening between the clypeus and the right maxillary sclerite. The distal end of this thickening (r. md.) unites with the right lateral margin of the pharynx as seen in cross-sections of the adult pharynx (fig. 55 and 56). Figures 33 and 35 do not show this connection because of the spreading of the heads.

The above nymphal evidence clearly demonstrates the homology between the asymmetrical mandibular parts of a species of Tubulifera and those of a species of Terebrantia. The evidence used in proving that the asymmetrical piercing organs of the Terebrantia are mandibles is equally applicable in demonstrating that the asymmetrical parts in the Tubulifera are also mandibles. One exception however occurs in the fact that in the nymph of Cephalothrips the invaginations for the anterior arms have not been identified along with other tentorial structures.

The mandibular parts of the adult (fig. 33) undergo a distinct modification due to the reduction in the size of the mouth-cone. In this change the left mandible (1. md.) retains its position between the clypeus and the left maxillary sclerite, but in so doing the heavy, proximal portion turns and forms a half circle. This modification has resulted in the formation of a distinct notch (n.) in the clypeus and the left maxillary sclerite. It has also resulted in the uniting of the meso-cephalic

corner of the maxillary sclerite and the base of the left mandible. The right mandible in the reduction of the mouth-cone has given rise to a distinct, crook-like, ental projection. The above modifications are typical for the suborder Tubulifera as far as observed.

Muir and Kershaw interpreted the left, asymmetrical piercing organ as a part of the maxillæ in their work on one species of Tubulifera. "The unpaired setæ arises from the left maxillæ and is a part thereof." It is readily understood how such an error came about, since only the adult stage of a single species of Tubulifera was studied. The connection of the left asymmetrical piercing organ in the adult with the left maxillary sclerite is secondary. This connection does not show in the nymph.

PHARYNX.

If one examines the mouth-cone of various species of thrips, a short, heavily chitinized, ham-shaped piece is always found just beneath the clypeus. Stained and sectioned material shows clearly that this piece is a structural modification of the alimentary canal, fitted for sucking and homologous with the pharynx of sucking insects (fig. 5, 6, 19, 27, 35, 38-46, 48, 49 and 52-59). Jordan figures this particular piece and calls it the hypopharynx of the pharynx, while his epipharynx is what we have interpreted to be the left mandible.

Structurally the pharynx consists of one piece except for a small, chitinized, transverse area (t. a.) at the caudo-dorsal end (fig. 46 and 48). However, in respect to size and shape the pharynx is divided into two regions. The ventral half is a small, chitinized tube which opens within the ental groove of the labrum, while the dorsal half widens out into a broad, thick region. The entire pharynx resembles a gourd dipper which has had removed from one side almost one-half of its enlarged portion, and across this cavity there has been placed a concave, elastic membrane (e.) to which muscles (d. m.) are attached. On the caudal side of the enlarged portion there are two small openings. Glandular ducts (d.) pass thru these openings and pour their secretions into the sucking chamber.

When the pharynx is sectioned in one of three planes, frontal, sagittal and transverse, it shows a centrally located canal extending thru its entire length. This lumen starts with

the mouth and continues dorsad of the pharynx as the oesophagus (oe.). Transverse sections of the pharynx show that it is firmly connected on its caudo-lateral aspects with the maxillary guides (mx. g.) and the mesal extensions (et. and l. et.) from the lateral margins of the maxillary sclerites and the labium. Over the lateral extensions (et.) the maxillary setæ (mx.) pass. The left mandible (l. md.) passes over an extension on the left lateral margin of the pharynx cephalad of the above extensions and the right, rudimentary mandible (r. md.) unites with the right margin of the pharynx. The above extensions and supports that connect with the pharynx serve to hold it in position while the large muscles are dilating its elastic membrane (e.). The above facts in regard to the pharynx hold for all thrips as far as observed.

Heliothrips femoralis.—Figures 38-46 and 58 give a much better idea of the general structure of the pharynx of Heliothrips than a lengthy discussion, consequently only the important and exceptional facts will be pointed out. The transverse sections (fig. 37-44) begin with a section thru the commissures between the supraoesophageal and suboesophageal ganglia and end at the tip of the mouth-cone. Every second or third section, ten microns in thickness, has been figured. In this series the lumen (l.), lateral extensions (et. and l. et.), piercing organs (mx., l. md. and r. md.), elastic membrane (e.), and muscles (d. m.) are shown. The connection of the muscles along the meson of the elastic membrane is characteristic of the Terebrantia. The large nucleated and cross-striated muscles, the dilators of the pharynx (fig. 58, d. m.), extend cephalad into the cavity of the head-capsule and unite with the ventral and cephalic areas. Two or more of these large muscle bands unite with a more or less chitinous tendon (c. t.) which arises from the elastic membrane. Besides these long muscles a number of short muscles extend between the small ventral portion of the pharynx and the clypeus.

The food of thrips is of a liquid nature and is sucked into the oesophagus in the following manner, judging from the structure of the parts. The muscles along the meson of the elastic membrane contract and dilate the lumen of the pharynx so that a partial vacuum is formed, and into this cavity is sucked the juice in which the tip of the mouth-cone is immersed. On

the relaxation of the dilating muscles the elastic membrane forces the food dorsad thru the open valve (v.) into the oesophagus. A more detailed account will be given of this process in the discussion of the pharynx of Cephalothrips.

Cephalothrips yuccæ.—In a similar manner, as with Heliothrips, figures 48-57 and 59 show the chief characteristics of the pharynx of the Tubulifera. In its main features it corresponds with the general description of the pharynx but in a few details it shows a greater degree of specialization than the pharynx of Heliothrips. In the first place it is strikingly ham-shaped and comparatively smaller. This difference in size is probably due to the reduction of the mouth-cone. Transverse sections show that the maxillary guides (mx. g.) unite with the pharynx for a short distance, and the extension over which the left mandible passes is the cephalic margin of the left, maxillary guide. The right, rudimentary mandible (r. md.) is not as large as in Heliothrips, however, it still retains its connection with the right side of the pharynx. The lumen (l.) of the pharynx is straight. The most striking difference between the pharynx of Heliothrips and Cephalothrips is in the arrangement of the dilating muscles.

A lateral view and transverse sections of the pharynx show a distinct chitinized plate (pt.) standing on edge along the meson of the elastic membrane (e.). The muscles are confined to the ventral and dorsal ends of this plate and the majority of them are connected to the chitinous tendon (c. t.) at the ventral end. These muscles, so-called ventral dilators (v. d. m.), extend into the head and unite with the vertex. There is a small band of muscles, the so-called dorsal dilators (d. d. m.), which extend between the dorsal end of the plate and the caudo-ventral area of the front. This arrangement of muscles is easily derived from the more generalized type found in Heliothrips. On the whole the form and arrangement of the parts in the pharynx of Cephalothrips would suggest that it is a more efficient organ than that of Heliothrips.

The lumen (l.) of the alimentary canal is cut off by a valve-like structure at the dorsal end of the pharynx (fig. 58a.). A prominent projection (p.) extends from the caudo-dorsal end of the pharynx into the lumen. This projection fits into a pocket (po.) on the opposite side. Under normal conditions

this valve is closed, consequently the lumen of the oesophagus is cut off from the pharynx while the elastic membrane is dilated. In suction the ventral dilating muscles (v. d. m.) contract and pull out the ventral portion of the elastic membrane. This results in the formation of a partial vacuum, and into this space the liquid food is drawn. The dorsal dilators (d. d. m.) now contract and dilate the dorsal end of the elastic membrane (e.). This dilation opens the valve separating the lumen of the pharynx and the oesophagus. While the dorsal dilators are contracting the ventral dilators relax and the ventral portion of the elastic membrane presses upon the enclosed food. This pressure forces the food dorsad in the lumen and then on the relaxation of the dorsal dilators the elastic membrane falls back into its normal position and the food is forced on and into the oesophagus. This completes one stroke or dilation of the pharynx of Cephalothrips.

The dilating muscles of the pharynx (d. m.) of Heliothrips, as before noted, are arranged along the meson of the elastic membrane (e.). This fact, along with the large size of the pharynx and its peculiar bent condition, would indicate that the elastic membrane does not have as distinct a ventro-dorsal dilation as that of Cephalothrips. Possibly the entire central portion of the membrane is dilated at one time and then as the large muscles relax the few strands of muscles uniting with the pharynx in the region of the valve contract and open the lumen. With the valve open and the elastic membrane pressing upon the enclosed food, the plant juice is forced into the oesophagus.

SALIVARY GLANDS.

Two or three kinds of salivary glands (fig. 15, 16, 23, 24, 30, 31, 38-44, 45, 49 and 51-55) are present in thrips and these are all located in the thorax and abdomen. Uzel has figured the glandular portion of the salivary glands located in the thorax and abdomen but does not figure the course of the ducts. In Uzel's figures two kinds of salivary glands are present in the thorax of Aeolothrips fasciatus, a form belonging to the suborder Terebrantia, and three kinds of salivary glands are found in the thorax of Trichothrips copiosa, a form belonging to the suborder Tubulifera. The species figured in this paper have only two kinds of salivary glands, which extend into the thorax and abdomen. These two kinds are paired and distinct.

Considerable variation occurs in regard to the exact location of these glands and the position and points of union of their ducts.

One of the two pairs of salivary glands (fig. 15 and 24, 31) in the thorax and abdomen of the two species here considered is long, tubular and more or less homogenous thruout its length 1. s. g.). This pair is located laterad or dorsad of the alimentary canal and continues caudad into the abdomen. Longitudinal sections thru these glands show that they are homogenous, nucleated and apparently syncitial.

The second pair of salivary glands (fig. 16 and 30) are short, thick and more or less irregular in outline and usually confined to the thorax (s. s. g.). The cells of these glands are large and the cell walls are distinct. The nuclei are prominent and stain deeply. The protoplasm of the tissue stains unevenly and is more or less filled with vacuoles. A distinct centrally located lumen extends thruout the entire length of the gland.

The above two pairs of salivary glands give rise to ducts (l. d. and s. d.) at their cephalic ends. The four ducts extend into the head laterad and dorsad of the oesophagus. In the region between the supraoesophageal and suboesophageal ganglia the ducts turn ventrad and continue to the y-shaped chitinous structure (y.) caudad of the pharynx (fig. 23, 45, 49, 58 and 59.). Within this structure or before entering it the four ducts unite into a common duct and this common duct (c. d.) continues ventrad to the apex of the mouth-cone. The secretions from the salivary glands are thus poured into the punctures in the host plant which are made by the mouth-parts. When thrips puncture green leaves or colored flowers the area about the puncture becomes light in color. This discoloration is undoubtedly due to the action of the salivary secretion on the plant tissue.

The y-shaped piece (y.) caudad of the pharynx in all thrips is a characteristic structure. In both suborders this piece is somewhat different in shape (fig. 35 and 47) but it has the same relation to the mouth-parts. There is a distinct muscle band or there may be several bands (mu.) extending between the base of the arms of the y and the dorsal part of the caudal aspect of the pharynx (ph.). Possibly, on contraction, these muscles move the y-shaped piece in such a manner as to control the flow from the salivary glands. The exact homology of the y-shaped

structure is not clear but its general position and structure, its opening into the mouth-cavity and its relation to the salivary ducts would indicate that it is homologous with the salivary syringe of the Hemiptera.

Heliothrips femoralis.—The long, narrow, tube-like glands (fig. 31 and 24) are located laterad of the alimentary canal (l. s. g.) and extend from the metathorax caudad to about the fourth abdominal segment. Figure 24 shows that the gland is narrow and has a straight lumen extending thruout its length. The ducts from these glands (fig. 31, l. d.) are enlarged and located dorsad of the oesophagus in the region of the prothorax and mesothorax. The enlarged portions of the ducts serve as reservoirs for the secretion. The ducts from these similar right and left glands unite with each other before entering the y-shaped structure caudad of the pharynx.

The short, thick, oval glands (fig. 30, s. s. g.) in the thorax are about the length of two segments and located laterad of the oesophagus. The right gland is usually confined to the metathorax and the first abdominal segment. The cells of these glands are exceedingly large and distinctly differentiated. One or two deeply staining, irregular nuclei can be seen in each cell, and the protoplasm of the cells stains more or less unevenly. The ducts from these glands (s. d.) have about the same thickness thruout. In the region of the head they are somewhat larger than the ducts from the above glands in the same region. The duct from the left gland unites with the duct from the right similar gland before entering the y-shaped piece (fig. 40, 45 and 58). Within the y-shaped piece the united ducts from the two kinds of glands join and form a common duct which continues to nearly the apex of the mouth-cone.

Cephalothrips yuccæ.—The long, tube-like glands of Cephalothrips (fig. 15, l. s. g.) are located laterad of the alimentary canal and extend from the prothorax into the first or second abdominal segment. These glands are homologous with the long, tube-like glands in Heliothrips, but they are thicker and have a sinuous lumen thruout their length. The cell consistency is about the same as in Heliothrips. The ducts extending from these glands into the head are very small and not dilated in the thorax.

The short, thick glands (fig. 16, s. s. g.) in the thorax of Cephalothrips are usually confined to the mesothorax and metathorax and located laterad of the alimentary canal. These glands are homologous with the short, thick glands of Heliothrips. In Cephalothrips these glands are longer and made up of smaller cells filled with vacuoles and granulated areas. The ducts from these glands (fig. 23) are of the same consistency thruout and only slightly larger than the ducts from the long tubular glands. The union of the salivary ducts in the head is somewhat different from that of Heliothrips. The ducts (fig. 23, 49, 52-55 and 59) of one side (l. d. and s. d.) unite and these united ducts meet in the center of the mouth-cone and form a common duct (c. d.) before entering the y-shaped piece.

HEAD-GLANDS.

A distinct, multinucleated and deeply staining tissue (h. g.) is present in definite parts of the head and mouth-cone of thrips and so far as known is described here for the first time (fig. 26, 38-43, 45, 49, 51-55, 58 and 59). This tissue, as far as can be determined, is of a glandular nature and it will be here designated as the head-gland. Its histological structure is different from that of the thoracic glands. Numerous and coarsely granulated nuclei are present; the cell walls cannot be differentiated; the protoplasm stains unevenly and no lumen could be identified. This tissue is most abundant in the members of the suborder Terebrantia. In Heliothrips (fig. 26, 38-43, 45 and 58) it occurs in three distinct regions. The most prominent massing occurs cephalad of the pharynx (h. g.) on the two sides of the dilating muscles. The extent and shape of these two masses varies considerably but the figures of the transverse sections and the lateral views of the pharynx show the usual distribution in this area. Distinct ducts (d.) arise from the dorsal ends of these masses and extend around the lateral sides of the oesophagus and turn ventrad and enter the two small openings on the caudal aspect of the pharynx (fig. 27, 45, 46 and 58). If the above masses are glandular then one can readily see how their secretions may be poured into the pharynx and aid in digestion. Besides the above glandular masses cephalad of the pharynx, similar tissue is present at the proximal end of the left and right mandibles.

The small mass on the left side (fig. 26) projects for a short distance into the hollow cavity of the left mandible. This is not the case with the mass adjacent to the right, rudimentary mandible. These two small masses are connected with the masses above described by means of fine ducts (du.). The exact extent of these ducts has not been definitely determined. It is possible that they unite with the ducts entering the pharynx. It is also possible that the secretions from the small mass within the left mandible passes out thru the minute lumen of the mandible. In the concave portion of the labrum small masses of tissue are present which resemble the above so-called glandular tissue. The extent of these masses varies and as yet no ducts have been observed in connection with them.

In Cephalothrips (fig. 48, 49-51, 55 and 59) the above supposed glandular tissue of the head is present but it is not so extensive. Two distinct masses can be identified cephalad of the pharynx and these give rise to ducts (d.) that empty into the pharynx as in Heliothrips. Also a small mass of similar tissue is located at the base of the left mandible but no such mass is found on the right side near the right mandible. No glandular tissue was found in the concave portion of the labium as in Heliothrips.

SUMMARY.

1. The general arrangement of the head and mouth-parts of the Thysanoptera and the Hemiptera is similar.

2. The resemblance between the mouth-parts of Thysanoptera and Orthoptera is apparently closer than the resemblance between the mouth-parts of Hemiptera and Orthoptera.

3. A comparison of the different structures of the two suborders shows clearly that the suborder Terebrantia is more generalized than the suborder Tubulifera.

4. The mouth-parts of thrips are fitted for sucking.

5. The parts of the mouth are in the form of a cone which encloses the piercing organs. The cone is composed of the clypeus (cl.) labrum (lr.), maxillary sclerites (mx. s.) and labium (lb.).

6. The mouth-parts of thrips are asymmetrical.

7. The asymmetry of the clypeus (cl.) and the maxillary sclerites (mx. s.) in the two suborders is of an entirely different nature.

8. The left asymmetrical piercing organ (l. md.) is the left mandible and the right, rudimentary piece (r. md.) extending between the pharynx (ph.) and the front (fr.) is the right, rudimentary mandible. These mandibular parts are present in all thrips as far as observed.

9. A pair of maxillae are present in all thrips. Each maxilla is divided into two parts; the asymmetrical or symmetrical, palpus-bearing, maxillary sclerite (mx. s.) and the symmetrical maxillary seta (mx.).

10. The tentorial structures in the nymph of Heliothrips can be homologized with the tentorium of Cicada. On the basis of this homology the greatly reduced tentorium of adult thrips can be interpreted.

11. The usual association between the tentorium and the mouth-parts in generalized insects is present in thrips and aids in interpreting the piercing organs. The maxillary setæ are closely associated with the posterior arms, while the left and right mandibles are associated with the invaginations of the anterior arms of the tentorium.

12. A comparison of the head of the nymph of Cephalothrips and the head of the adult of Heliothrips shows clearly the homology existing between the two suborders in respect to the piercing organs.

13. The semi-pupal stage of Cephalothrips shows a distinct reduction in the mouth-cone. The peculiar shape of the left mandible and the point of attachment of the maxillary setæ in the adult is in part due to this reduction.

14. The pharynx at the anterior end of the alimentary canal is modified into a distinct and characteristic sucking apparatus.

15. Two kinds of paired salivary glands are found in the thorax and abdomen of the two species here figured. The ducts from these glands unite and pass into a y-shaped structure caudad of the pharynx.

16. The tissue in the head, here called head-glands, has a similar structure and a definite arrangement. Ducts can be traced from the majority of these glands to the two small openings on the caudal aspect of the pharynx.

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EXPLANATION OF PLATES.

Plate I.

Fig. 1. Ventral aspect of the head of Heliothrips femoralis.
Fig. 2. Left lateral aspect of the head of Heliothrips femoralis.
Fig. 3. Left lateral aspect of the mouth-cone of Thrips physapus.
Fig. 4. Antenna of Heliothrips femoralis.
Fig. 5. Right lateral aspect of the head of Heliothrips femoralis.
Fig. 6. Right lateral aspect of the mouth-cone of Thrips physapus.
Fig. 7. Dorsal aspect of the head-capsule of Heliothrips femoralis.

Plate II.

Fig. 8. Ventral aspect of the head of Cephalothrips yuccæ.
Fig. 9. Dorsal aspect of the head-capsule of Cephalothrips yuccæ.
Fig. 10. Antenna of Cephalothrips yuccæ.
Fig. 11. Left lateral aspect of the head of Cephalothrips yuccæ.

Plate III.

Fig. 12. Left lateral aspect of the head of the nymph of Heliothrips femoralis.
Fig. 13. Ventral aspect of the head of the nymph of Heliothrips femoralis.
Fig. 14. Ental view of a maxillary sclerite of Thrips physapus.
Fig. 15. Longitudinal section of the proximal and distal portions of a long, salivary gland of Cephalothrips yuccæ.
Fig. 16. Longitudinal section of a short, salivary gland of Cephalothrips yuccæ.
Fig. 17. Ventral aspect of the head of the nymph of Cephalothrips yuccæ.
Fig. 18. Left lateral aspect of the head of the nymph of Cephalothrips yuccæ.
Fig. 19. Right lateral aspect of the head of the nymph of Heliothrips femoralis.
Fig. 20. Ventral aspect of the head of the semi-pupa of Cephalothrips yuccæ.
Fig. 21. Ectal aspect of a maxillary sclerite of Frankliniella tritici.

PLATE IV.

Fig. 22. Ental view of the ventral aspect of the mouth-cone and a portion of the head-capsule of the nymph of Cephalothrips yuccæ. The parts have been spread and the pharynx omitted.
Fig. 23. The union of the salivary ducts in Cephalothrips yuccæ. The solid lines indicate the structures in a sagittal section, ten microns thick.
Fig. 24. Distal portion of a longitudinal section of the long salivary glands of Heliothrips femoralis.
Fig. 25. Manner of interlocking of the grooved maxillary setae of Cephalothrips yuccæ when projected from the mouth-cone.
Fig. 26. Sagittal section of the left, asymmetrical mandible of Heliothrips femoralis.
Fig. 27. Ental view of the ventral aspect of the mouth-cone and a portion of the head-capsule of Heliothrips femoralis. The parts have been spread and the maxillary extensions (et.) omitted.
Fig. 28. Ental view of the ventral aspect of the mouth-cone and a portion of the head-capsule of the nymph of Heliothrips femoralis. The parts have been spread and the pharynx omitted.
Fig. 29. The tentorium of Cicada septendecim.
Fig. 30. Longitudinal section of the short salivary gland of Heliothrips femoralis.
Fig. 31. Longitudinal section thru a dilated duct of a long salivary gland of Heliothrips femoralis. The distal portion of the gland shown in figure 24.
Fig. 32. Ental view of the right maxillary sclerite of Heliothrips femoralis.

PLATE V.

Fig. 33. Ental view of the ventral aspect of the mouth-cone and a portion of the head-capsule of Cephalothrips yuccæ. The parts have been spread and the pharynx omitted.
Fig. 24. Ental aspect of the left maxillary sclerite of Cephalothrips yuccæ.
Fig. 35. Ental view of the ventral aspect of the mouth-cone of Cephalothrips yuccæ. The parts have been spread.
Fig. 36. Ental aspect of the right maxillary sclerite of Cephalothrips yuccæ.

PLATE VI.

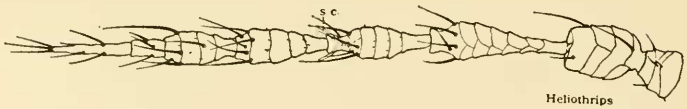
Fig. 37. Frontal section thru the commissures connecting the supraoesophageal and suboesophageal ganglia of Heliothrips femoralis.
Fig. 38–44. Cross-sections of the pharynx from the dorsal end to the tip of the mouth-cone of Heliothrips femoralis. Each second or third section figured.
Fig. 45. Lateral view of the pharynx of Heliothrips femoralis.
Fig. 46. Caudal aspect of the pharynx of Heliothrips femoralis. The extensions over which the maxillary setae pass, have been omitted.
Fig 47. Caudal aspect of the Y-shaped piece located caudad of the pharynx.
Fig. 48. Caudal aspect of the pharynx and labrum of Cephalothrips yuccæ. The extensions, over which the maxillary setae and left mandible pass, have been omitted.
Fig. 49. Lateral view of the pharynx of Cephalothrips yuccæ.
Fig. 50. Frontal section thru the commissures connecting the supraoesophageal and suboesophageal ganglia of Cephalothrips yuccæ.
Fig. 51. Cross-section of the oesophagus of Cephalothrips yuccæ at the point where ducts from the head-glands (d.) pass laterad of the oesophagus in their extension from the head-glands to the two openings on the caudal aspect of the pharynx.
Fig. 52–57. Cross-sections of the pharynx from the dorsal end to the tip of the mouth-cone of Cephalothrips yuccæ. Each second or third section figured.

PLATE VII.

Fig. 58. Sagittal section thru the head and prothorax of Heliothrips femoralis. The salivary glands have been omitted.
Fig. 58a. The valve at the dorsal end of the pharynx of figure 58 more enlarged.
Fig. 59. Sagittal section thru the head and a portion of the prothorax of Cephalothrips yuccæ. The salivary glands have been omitted.
Fig. 60. Caudal aspect of the labium of Heliothrips femoralis.
Fig. 61. Caudal aspect of the labium of Cephalothrips yuccæ.

LIST OF ABBREVIATIONS.

a. a. Anterior arms of the tentorium.
al. c. Alimentary canal.
ant. Antennae.
c. a. Caudal projections or arms.
c. d. Common duct of the salivary glands.
cl. Clypeus.
co. Commissure.
c. t. Chitinous tendon.
d. Duct of the head-glands.
d. a. Dorsal arms of the tentorium.
d. d. m. Dorsal dilating muscles of the pharynx.
d. l. Dilated lumen.
d. m. Dilating muscles of the pharynx.
du. Duct from glandular tissue near mandible.
e. Elastic membrane.
et. Ental extensions of the maxillary sclerites.
f. Fold in the clypeus.
fr. Front.
g. Gena.
h. g. Head-glands.
i. a. Invaginations of the anterior arms of the tentorium.
i. d. Invaginations of the dorsal arms of the tentorium.
i. p. Invaginations of the posterior arms of the tentorium.
l. Lumen.
lb. Labium.
lb. pl. Labial palpus.
l. d. Duct of the long, salivary gland.
l. et. Ental extensions of the labium.
l. md. Left mandible.
lr. Labrum.
l. s. g. Long salivary gland.
m. Mentum.
me. Membranous area.
mu. Muscle.
mx. Maxillary seta.
mx. g. Maxillary guide.
mx. p. Maxillary pillar.
mx. pl. Maxillary palpus.
mx. s. Maxillary sclerite.
n. Notch.
ne. Nerve.
o. Occiput.
oc. Ocellus.
oe. Oesophagus.
on. Oenocyte.
p. Pharyngeal projection.
p. a. Posterior arms of the tentorium.
ph. Pharynx.
p. l. Prothoracic leg.
po. Pharyngeal pocket.
pr. Paraglossa.
p. s. Prothoracic sclerite.
pt. Chitinous plate.
r. md. Right rudimentary mandible.
rt. Reticulation.
s. Suture.
s. c. Sense cone.
s. d. Duct of the short salivary gland
sm. Submentum.
s. s. g. Short salivary gland.
st. Caudal head-strip.
sub. Suboesophageal ganglion.
supra. Supraoesophageal ganglion.
t. Thorax.
t. a. Transverse area of the pharynx.
v. d. m. Ventral, dilating muscles of pharynx.
vt. Vertex.
x. Ental thickening on margin of head-capsule.
xc. Union of the anterior and posterior arms.
y. Y-shaped pharyngeal piece.
z. Ental thickening on margin of head-capsule.
zc. Piece connecting the united arms.



Heliothrips
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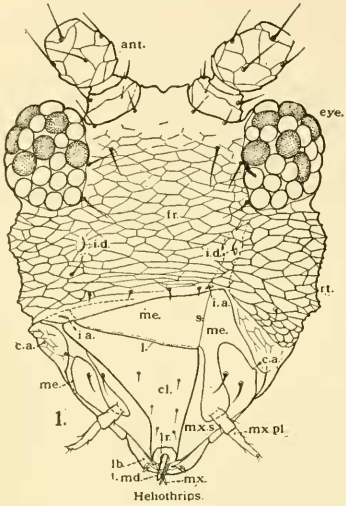

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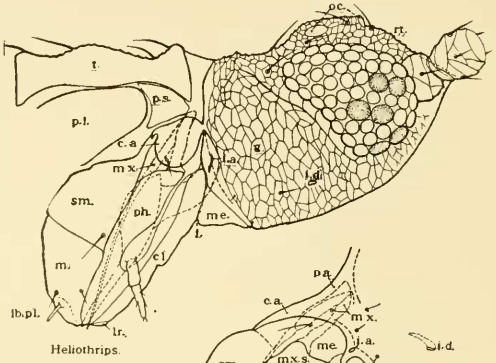

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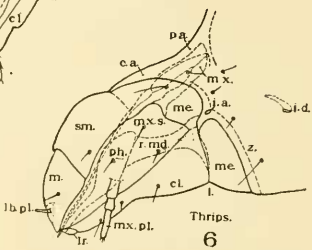

Thrips.
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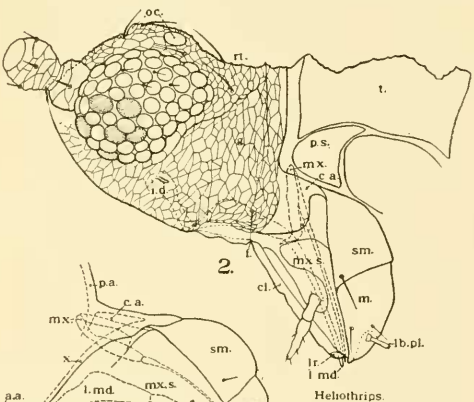

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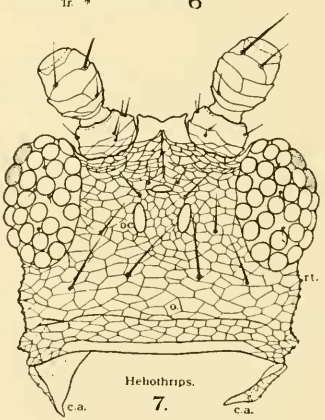

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Thrips.
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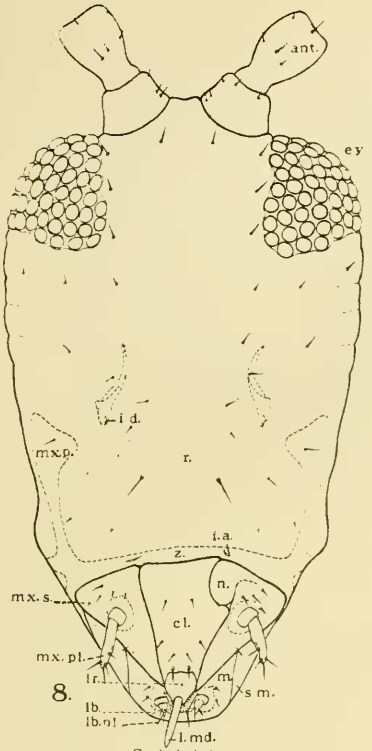
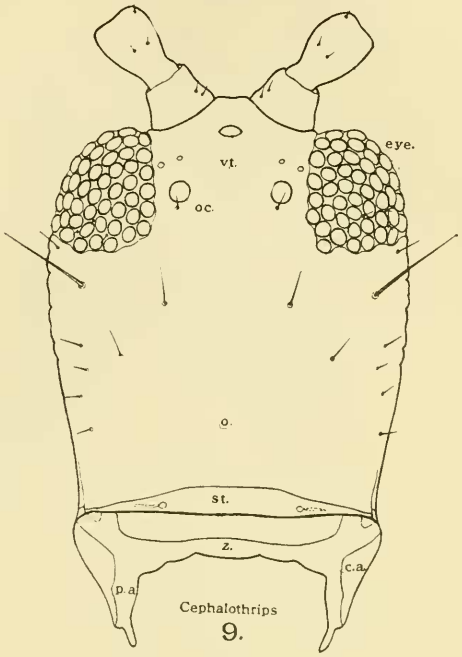
Alvah Peterson.

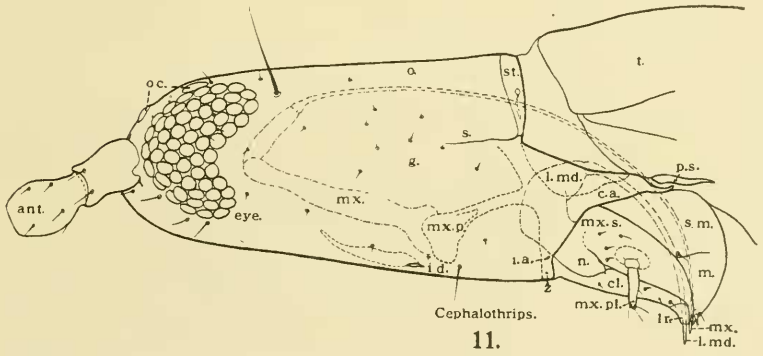


8. Cephalothrips



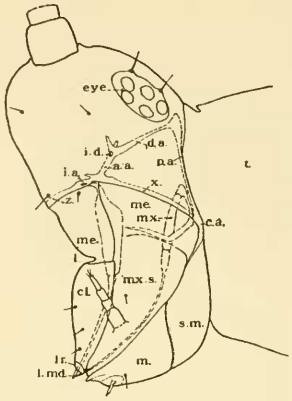
9. Cephalothrips

10 Cephalothrips.



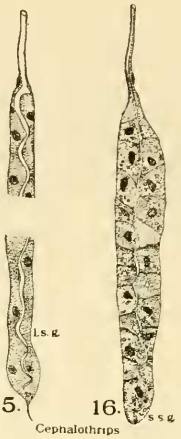
11. Cephalothrips.

Alvah Peterson.



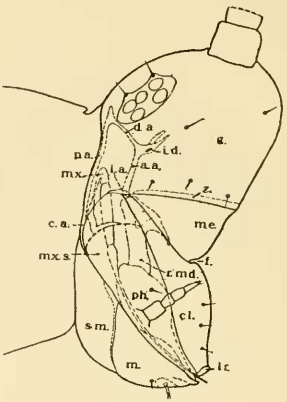
Heliothrips.

12.



15. 16.

Cephalothrips



Heliothrips.

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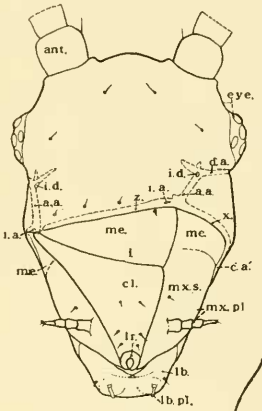

Heliothrips.

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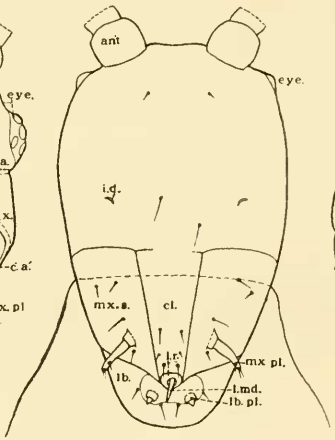

Cephalothrips.

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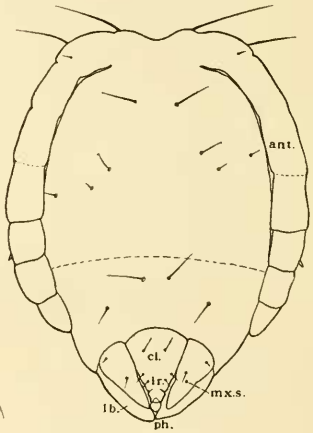

Cephalothrips.

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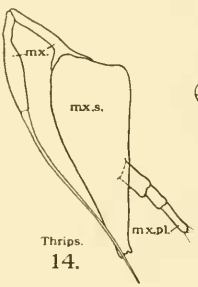

Thrips.

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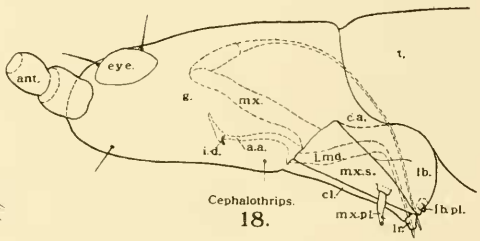

Cephalothrips.

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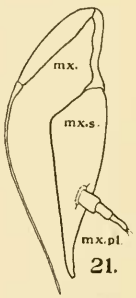
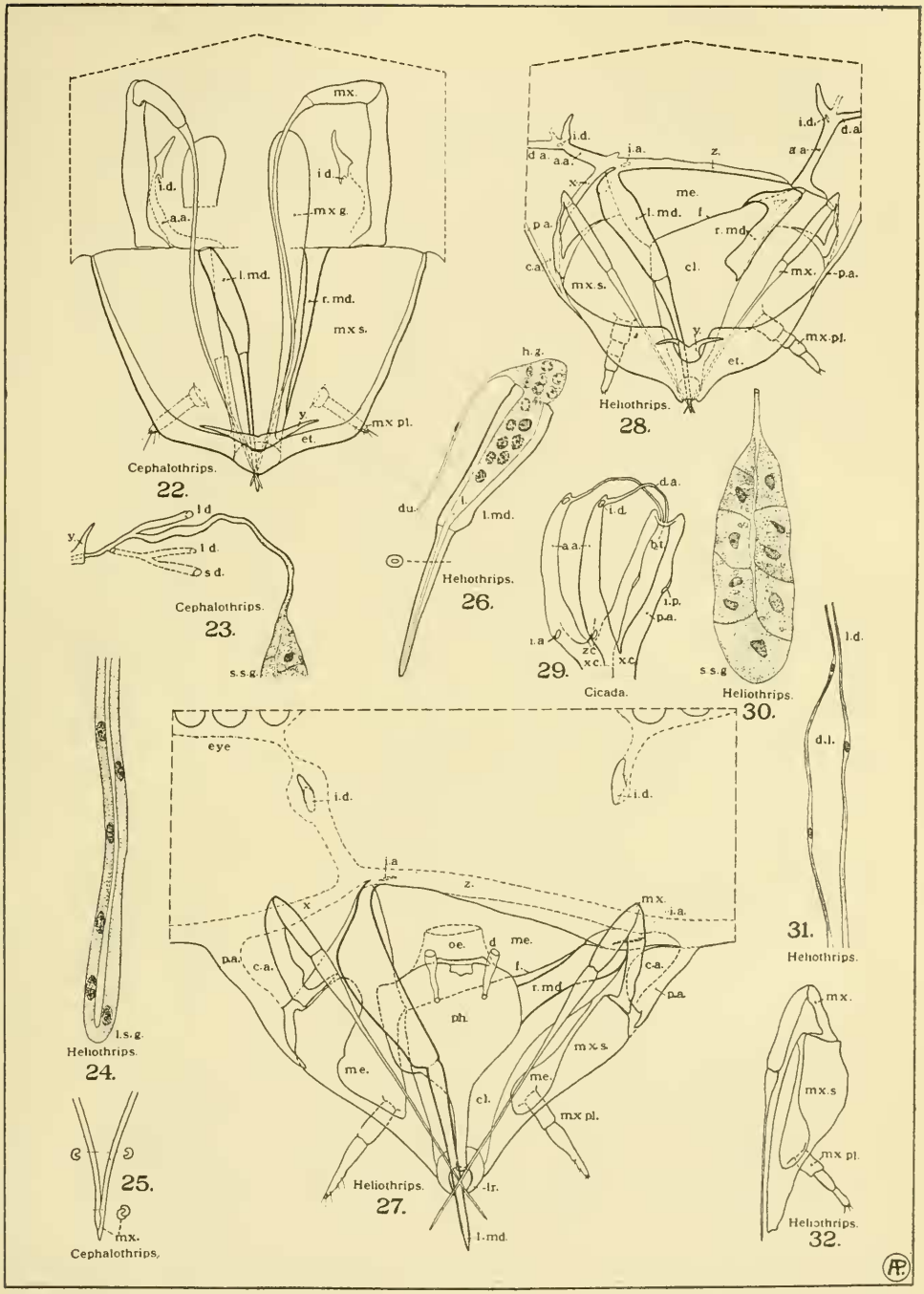


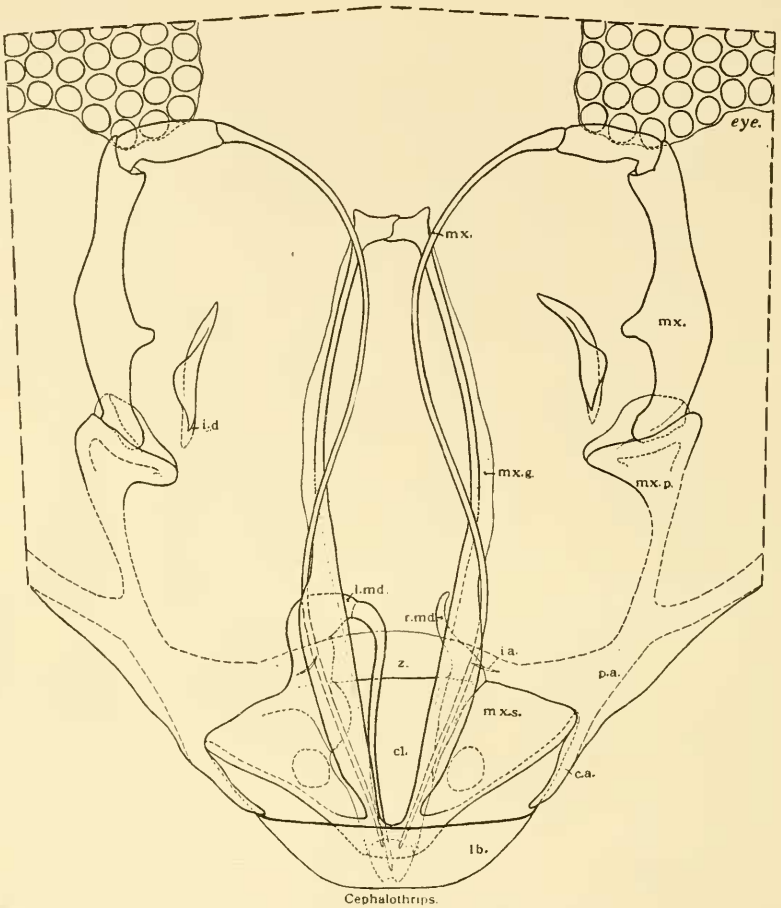
Frankliniella

21.

Alvah Peterson.



Alvah Peterson.



Cephalothrips.

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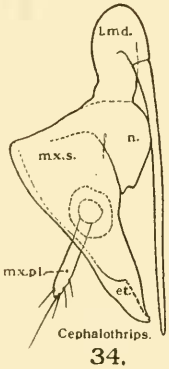

Cephalothrips.

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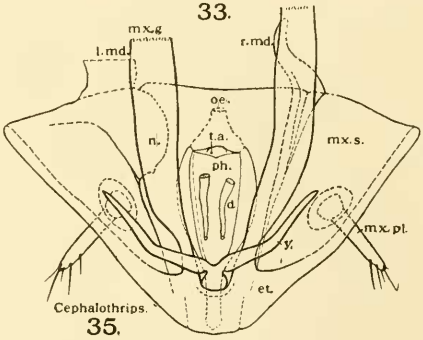
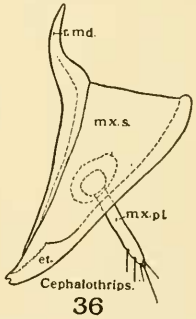


Cephalothrips.

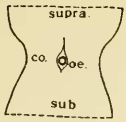
35.



Cephalothrips.

36

Alvah Peterson.



Heliothrips.
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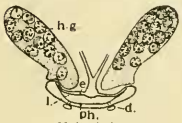
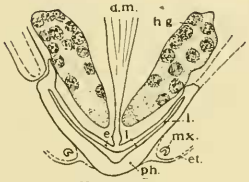


Heliothrips.
38



Heliothrips.
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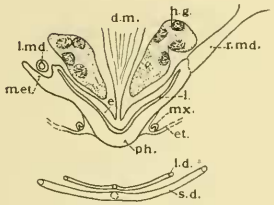

Heliothrips.
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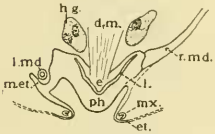

Heliothrips.
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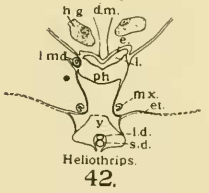

Heliothrips.
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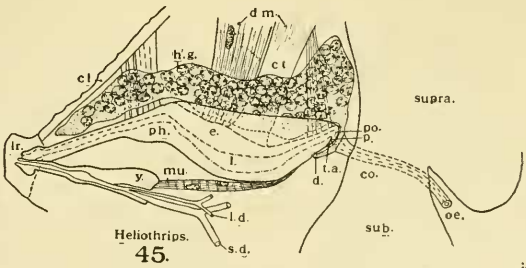

Heliothrips.
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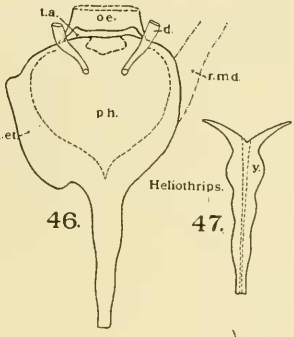

Heliothrips.
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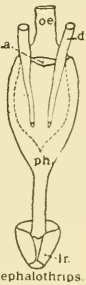

Cephalothrips.
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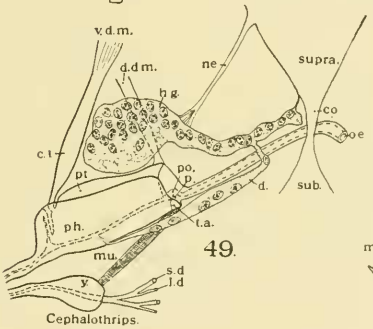

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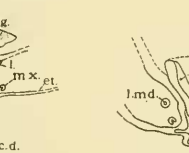
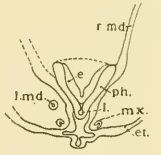
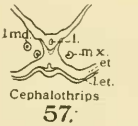


Heliothrips.
43.



Cephalothrips.
56.

Heliothrips.
44.



Cephalothrips
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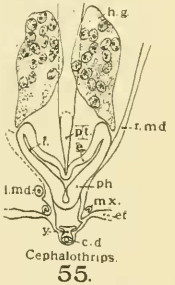
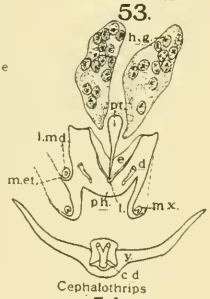


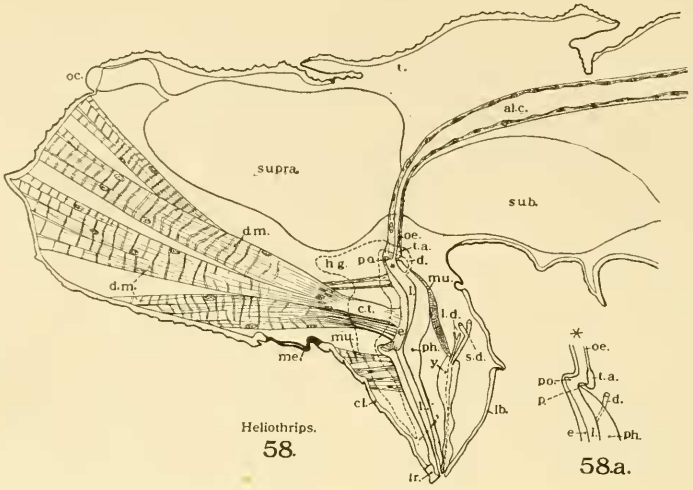
Cephalothrips.
52.

Cephalothrios
53.



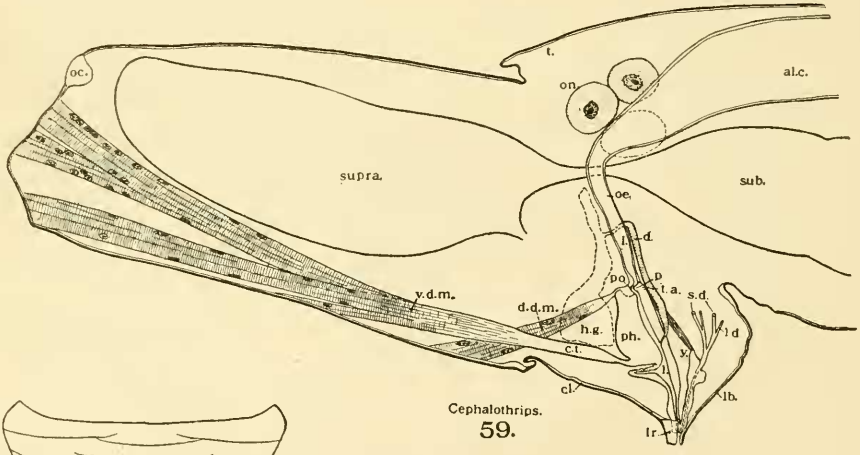
Cephalothrips
54.

Cephalothrips.
55.



Heliothrips.
58.

58.a.



Cephalothrips.
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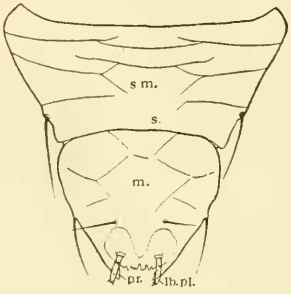

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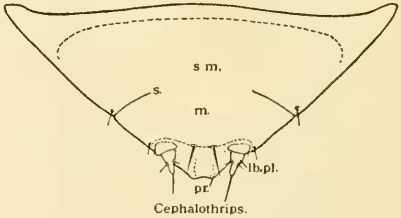

Cephalothrips.
61.

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